Research

Auditory brainstem response latencies in children with global developmental delay at Dr. Cipto Mangunkusumo Hospital

Muhammad Ade Rahman*, Tri Juda Airlangga*,
Fikry Hamdan Yasin*, Rini Sekartini, Achmad Rafli**, Ferdi Afian*****
*Department of Otorhinolaryngology Head and Neck Surgery, Faculty of Medicine, Universitas Indonesia/Dr. Cipto Mangunkusumo National General Hospital, Jakarta, Indonesia
**Department of Pediatric, Faculty of Medicine, Universitas Indonesia/ Dr. Cipto Mangunkusumo National General Hospital, Jakarta, Indonesia
***Department of Community Medicine, Faculty of Medicine, Universitas Indonesia, Jakarta, Indonesia

ABSTRACT

Background: Global developmental delay (GDD) affects multiple developmental domains and remains a major concern in early childhood. The auditory system plays a key role in language development, and the Auditory Brainstem Response (ABR) test provides an objective measure of auditory pathway maturation. However, data on ABR wave latencies among children with GDD who have normal predicted hearing thresholds are limited. **Purpose:** To describe absolute and interwave latencies of ABR waves I, III, and V, and to compare latencies of ABR waves across demographic and perinatal clinical characteristics in children with GDD. **Method:** A cross-sectional analytical study was conducted using medical record data from 70 children aged 6 months to 5 years with GDD at Dr. Cipto Mangunkusumo Hospital between January 2021 and May 2025. All subjects had normal predicted hearing thresholds (≤30dB) in ABR result and passed Distortion Product Otoacoustic Emission (DPOAE) screening. Comparations between risk factors (age, gender, gestational age, birth weight, NICU admission, asphyxia, and hyperbilirubinemia) and ABR latencies were analyzed using t-test or Mann–Whitney test. **Result:** Most subjects were male (71.4%) with a median age of 25 months. The language domain was most frequently affected (92.9%). Male subjects had a significantly longer absolute latency of wave V in the left ear compared to females (6.10±0.31 ms; $p < 0.05$). **Conclusion:** Male gender with normal predicted hearing threshold had significant difference in the left-ear wave V latency compared to female. ABR is a valuable tool for early detection of auditory pathway maturation delay in at-risk children.

Keywords: auditory brainstem response, children, global developmental delay, latency, risk factors

ABSTRAK

Latar belakang: *Keterlambatan perkembangan global (KPG) memengaruhi beberapa ranah perkembangan dan merupakan masalah utama pada masa kanak-kanak. Sistem pendengaran berperan penting dalam perkembangan bahasa, dan pemeriksaan Auditory Brainstem Response (ABR) memberikan penilaian objektif terhadap maturasi jalur pendengaran. Namun, data mengenai masa latensi gelombang ABR pada anak dengan KPG yang memiliki prediksi ambang dengar normal masih terbatas.* ***Tujuan:*** *Mendeskripsikan masa latensi absolut dan antar gelombang I, III, dan V pada pemeriksaan ABR, serta membandingkan nilai latensi tersebut berdasarkan karakteristik demografis dan klinis perinatal pada anak dengan KPG.* ***Metode:*** *Penelitian analitik observasional dengan desain potong lintang menggunakan data rekam medis 70 anak usia 6 bulan hingga 5 tahun dengan KPG di Rumah Sakit Cipto Mangunkusumo periode Januari 2021–Mei 2025. Seluruh subjek memiliki hasil* ABR *prediksi ambang dengar normal (≤30 dB) dan hasil* Distortion Product Otoacoustic Emission (DPOAE)

"pass". *Hubungan antara faktor risiko (usia, jenis kelamin, usia gestasi, berat saat lahir, riwayat perawatan NICU, asfiksia, dan hiperbilirubinemia) dengan masa latensi* ABR *dianalisis menggunakan uji-*t *atau* Mann–Whitney. ***Hasil:*** *Sebagian besar subjek berjenis kelamin laki-laki (71,4%) dengan usia median 25 bulan. Ranah bahasa merupakan ranah yang paling sering mengalami keterlambatan (92,9%). Jenis kelamin laki-laki memiliki masa latensi absolut gelombang V pada telinga kiri yang bermakna lebih panjang dibanding jenis kelamin perempuan (6,10±0,31 ms; p < 0,05). Faktor risiko lainnya tidak menunjukkan hubungan signifikan.* ***Kesimpulan:*** *Jenis kelamin laki-laki dengan prediksi ambang dengar normal menunjukan perbedaan bermakna secara statistik pada masa latensi absolut gelombang V telinga kiri dibandingkan jenis kelamin perempuan. Pemeriksaan* ABR *penting untuk deteksi dini keterlambatan maturasi jalur pendengaran pada anak berisiko.*

Kata kunci: *auditory brainstem response, anak-anak, keterlambatan perkembangan, latensi, faktor risiko*

Correspondence address: Muhammad Ade Rahman. Department of Otorhinolaryngology Head and Neck Surgery, Faculty of Medicine, Universitas Indonesia/Dr. Cipto Mangunkusumo National General Hospital, Jakarta, Indonesia. Email: m.ade.rahman@gmail.com

INTRODUCTION

Global developmental delay (GDD) is defined as a delay in two or more developmental domains in children under five years of age.[1] The prevalence of GDD is estimated at approximately 1–3%, with a reported rate of 2.3% at Dr. Cipto Mangunkusumo Hospital.[2,3] Among the developmental domains, language development is most frequently affected, with prevalence varying across countries: 2–19% in the United States, 34.2% in India, 14.5% in Palestine, and 62.9% in Indonesia.[4-7]

During the first year of life, the auditory system of infants and children begins to play a crucial role in distinguishing various sound stimuli from the environment, which forms the foundation for language acquisition.[8] The function of the auditory system in this population can be evaluated using Auditory Brainstem Response (ABR), an examination that records the electrical activity generated along the auditory pathway, particularly at the level of the brainstem.[9]

Fuess et al.[10] reported that infants and children with delayed language development may experience delayed maturation of the auditory pathway at the brainstem level. This maturation process may be influenced by several risk factors affecting auditory function, including age, gender, gestational age, birth weight, history of neonatal intensive care unit (NICU) treatment, asphyxia, and hyperbilirubinemia. With increasing age, a shortening of wave latency occurs, particularly in wave V.[11] Several studies had demonstrated that males tend to have longer latencies compared to females, while premature infants often exhibit prolonged latencies in waves III and V.[12,13] Moreover, low birth weight, NICU treatment history, asphyxia, and hyperbilirubinemia might interfere with the maturation of the auditory brainstem pathway, which was reflected in altered wave latencies observed during ABR examination.[14-17]

Therefore, these risk factors may disrupt the maturation of the auditory system, potentially contributing to delayed language development in children with GDD. ABR serves as an important auxiliary examination for assessing auditory system maturity; hence, further research is required to describe and compare between ABR wave latency and risk factors in GDD at Dr. Cipto Mangunkusumo Hospital.

METHOD

This study employed an observational analytic design with a cross-sectional approach, to describe the absolute latencies of waves I, III, and V, as well as the interwave latencies of I–III, III–V, and I–V, in children with global developmental delay (GDD) aged 6 months to 5 years who had normal hearing thresholds (≤30 dB). The study also aimed to compare these latencies across risk factors including age, gender, gestational age, low birth weight, history of neonatal intensive care unit (NICU) admission, asphyxia, and hyperbilirubinemia in GDD with normal hearing threshold. Data collection was conducted over a one-month period using secondary data from medical records between January 2021 and May 2025.

The study subjects included infants and children aged 6 months to 5 years diagnosed with GDD, confirmed by Denver II developmental screening results from the Pediatric Social Division, Department of Child Health. Eligible subjects were those with "pass" results on Distortion Product Otoacoustic Emission (DPOAE) testing and normal predicted hearing thresholds on Auditory Brainstem Response (ABR) test, using click stimuli at an intensity of 20–30 dB. Exclusion criteria included evidence of auditory neuropathy spectrum disorder (ANSD), congenital syndromic or dysmorphic features.

A minimum of 70 subjects were recruited using consecutive sampling. Data were analyzed using SPSS version 22, with *t*-test applied for normally distributed data, and Mann–Whitney test for non-normally distributed data. Ethical approval for this study was obtained from the Faculty of Medicine, Universitas Indonesia/Dr. Cipto Mangunkusumo Hospital Ethics Committee (approval number: KET–748/UN2.F1/ETIK/PPM/00.02/2025).

RESULT

In this study, a total of 70 subjects aged 6 months to 5 years with global developmental delay (GDD) who had undergone Auditory Brainstem Response (ABR) at Dr. Cipto Mangunkusumo Hospital between January 2021 and May 2025 were included. The study population exhibited multiple perinatal risk factors. Prematurity (gestational age <37 weeks) was observed in 38.6% of the subjects, whereas 31.4% were born with low birth weight (<2500 grams). A history of NICU admission was present in 35.7% of the population, while asphyxia and hyperbilirubinemia were reported in 30% and 12.9% of subjects, respectively. Another identified risk factor was microcephaly, which was found in 32.9% of the participants. Based on the Denver II developmental assessment, the most commonly delayed developmental domain was language, observed in 65 subjects (92.9%).

The results of this study demonstrated that most absolute and interwave ABR latencies showed a normal distribution, except for the absolute latency of wave III in the right ear and wave I in the left ear. The percentage of successfully recorded data varied from 48.6% to 100%, with the most complete recordings obtained for wave V in both ears. In contrast, the recordings for wave I in the left ear (48.6%) and wave III in the right ear (58.6%) were the least complete. This variation in data completeness affected the recording of interwave latencies I–III, III–V, and I–V, which might have influenced the study outcomes. The ABR wave latency values were presented in Table 1.

Table 1. ABR wave latency in children with GDD

ABR wave latency	Right ear (ms)	Left ear (ms)
Wave I	2.07±0.32	1.91, 0-2.86
Wave III	4.16, 2.66-4.84*	4.18±0.29
Wave V	6.04±0.39	6.05±0.31
Wave I-III	2.07±0.32	2.08±0.36
Wave III-V	1.89±0.20	1.88±0.23
Wave I-V	3.95±0.39	3.97±0.46

Note: Data were presented as mean±standard deviation (SD)
*Data were presented as median (minimum-maximum) because the distribution data was non-normal

This study demonstrated that male subjects had a significantly longer in the absolute latency of wave V in the left ear compared to female subjects (6.10±0.31 ms vs 5.93±0.30 ms; mean difference of 0.17 ms; p value < 0.05). No statistically significant differents was observed in the absolute latencies of waves I, III, and V and the interwave latencies I–III, III–V, and I–V when compared across age, gestational age, birth weight, history of NICU admission, asphyxia, and hyperbilirubinemia. Additionally, there were no significant differences in the absolute latencies of waves I and III or the interwave latencies I–III, III–V, and I–V in regard to gender. The significance of the ABR wave latency regarding risk factor showed in Table 2 and Table 3.

Table 2. Comparation of age, gender, gestational age, birth weight, history of NICU admission, asphyxia, and hyperbilirubinemia with absolute latency of waves I, III, and V in right-ear ABR among children with global developmental delay

Variable	Wave I mean±SD	*p* value	Mean Difference (95%CI)	Wave III* median (min-max)	*p* value	Mean Difference (95%CI)	Wave V mean±SD	*p* value	Mean Difference (95%CI)
Age									
6-24 months	2.17±0.36	0.135	0.17 (-0.05-0.39)	4.20(2.66-4.82)	0.291	-	6.09±0.49	0.382	0.08 (-0.10-0.27)
25-60 months	2.00±0.27			4.11(3.70-4.70)			6.00±0.28		
Gender									
Male	2.08±0.33	0.864	0.02 (-0.22-0.26)	4.16(3.74-4.82)	0.341	-	6.09±0.33	0.144	0.15 (-0.05-0.36)
Female	2.06±0.31			4.11(2.66-4.49)			5.93±0.51		
Gestational age									
Premature	2.18±0.34	0.149	0.17 (-0.06-0.40)	4.15(3.70-4.82)	0.728	-	6.09±0.35	0.809	0.02 (-0.17-0.22)
Normal	2.05±0.31			4.16(2.66-4.70)			6.03±0.41		
Birth weight									
Low	2.17±0.34	0.329	0.13 (-0.13-0.39)	4.11(3.70-4.82)	0.837	-	6.08±0.35	0.567	0.06 (-0.14-0.26)
Normal	2.04±0.31			4.16(2.66-4.70)			6.03±0.41		
NICU admission									
Yes	2.13±0.35	0.512	0.07 (-0.16-0.31)	4.20(2.66-4.82)	0.511	-	6.04±0.54	0.946	-0.06 (-0.20-0.19)
No	2.05±0.30			4.13(3.74-4.70)			6.05±0.29		
Asphyxia									
Yes	2.15±0.38	0.477	0.09 (-0.17-0.36)	4.22(3.70-4.82)	0.211	-	6.10±0.38	0.465	0.07 (-0.13-0.28)
No	2.05±0.30			4.11(2.66-4.70)			6.02±0.40		
Hyperbilirubinemia									
Yes	2.27±0.30	0.210	0.21 (-0.12-0.55)	4.20(3.91-4.49)	0.806	-	5.97±0.28	0.536	-0.08 (-0.37-0.19)
No	2.05±0.32			4.11(2.66-4.82)			6.06±0.41		

Table 3. Comparation of age, gender, gestational age, birth weight, history of NICU admission, asphyxia, and hyperbilirubinemia with absolute latency of waves I, III, and V in left-ear ABR among children with global developmental delay

Variable	Wave I median (min-max)	*p* value	Mean Difference (95%CI)	Wave III mean±SD	*p* value	Mean Difference (95%CI)	Wave V mean±SD	*p* value	Mean Difference (95%CI)
Age									
6-24 months	2.22(0.00-2.82)	0.216	-	4.21±0.29	0.445	0.05 (-0.09-0.20)	6.11±0.34	0.188	0.10 (-0.05-0.25)
25-60 months	1.87(1.32-2.86)			4.15±0.30			6.01±0.28		
Gender									
Male	2.08(1.32-2.86)	0.176	-	4.22±0.30	0.085	0.13 (-0.02-0.30)	6.10±0.31	0.044	0.17 (0.004-0.33)
Female	1.78(0.00-2.78)			4.08±0.27			5.93±0.30		
Gestational age									
Premature	2.18(0.00-2.86)	0.577	-	4.14±0.31	0.434	0.06 (-0.20-0.09)	6.06±0.33	0.884	0.01 (-0.14-0.17)
Normal	1.82(1.32-2.82)			4.20±0.29			6.05±0.30		
Birth weight									
Low	2.20(0.00-2,74)	0.754	-	4.14±0.32	0.527	0.05 (-0.20-0.10)	6.10±0.36	0.460	0.06 (-0.10-0.22)
Normal	1.87(1.32-2.86)			4.19±0.29			6.04±0.30		
NICU admission									
Yes	2.07(0.00-2.78)	0.945		4.14±0.32	0.448	0.06 (-0.20-0.09)	6.06±0.35	0.988	-0.001 (-0.16-0.15)
No	1.89(1.32-2.86)		-	4.20±0.29			6.06±0.29		
Asphyxia									
Yes	2.07(1.32-2.74)	0.889	-	4.16±0.35	0.710	0.03 (-0.18-0.13)	6.09±0.35	0.604	0.04 (-0.12-0.20)
No	1.89(0.00-2.86)			4.19±0.27			6.04±0.30		
Hyperbilirubinemia									
Yes	2.24(1.62-2.57)	0.552	-	4.03±0.27	0.106	-0.17 (-0.38-0.04)	5.88±0.30	0.066	-0.21 (-0.43-0.14)
No	1.87(0.00-2.86)			4.20±0.30			6.08±0.31		

DISCUSSION

This study demonstrated that infants and children with GDD were predominantly male, and mostly aged between 25 and 60 months. These findings were consistent with those of Suwarba et al.[3], who reported that this age range represented the group with the highest prevalence of GDD. In addition, microcephaly was observed in 32.9% of participants in this study, indicating a possible association with comorbid conditions including visual impairment, hearing loss, and cerebral palsy, such as reported by Aggrawal et al.[18] regarding the relationship between microcephaly and varius comorbidities.

Language development delay was the most frequently affected domain in this study, consistent with the characteristics reported by Suwarba et al.[3]

Analysis of absolute wave latencies in the ABR revealed that only wave V in the left ear showed a significant difference with male gender as a risk factor. Studies by Lotfi[12] and Angrisani[14] reported that males tend to have longer wave V latencies, possibly due to differences in cochlear length and head size. Wave V is also considered the most stable and sensitive indicator for evaluating the maturation of the auditory brainstem pathway, given its large amplitude and ease of identification.[11,19–21]

In contrast, the absolute latencies of waves I and III, as well as the interpeak latencies (I–III, III–V, and I–V), showed no significant differences with the risk factors examined. This finding suggested that myelination of the peripheral auditory nerve was already matured at an early age, whereas central auditory maturation continues for a longer period. The result of this study was consistent with Jiang at al.[22], which reported the maturation of the peripheral nervous system occurred earlier than the central nervous system. Several technical limitations, such as suboptimal recording of waves I and III, might have influenced the interpretation of the results.

This research served as a preliminary study providing an overview of the relationship between perinatal risk factors and the maturation of auditory pathways in children with GDD using ABR test. Increased clinical vigilance is required among pediatricians and otorhinolaryngologists for the early detection of central hearing disorders, particularly in male children with risk factors such as premature gestational age, low birth weight, NICU admission, asphyxia, and hyperbilirubinemia. ABR testing is recommended before six months of age and should be re-evaluated before 18 months to ensure optimal auditory maturation. Early intervention through speech therapy and language stimulation should be initiated before the age of three years to minimize disability due to delayed maturation of the auditory system.

Furthermore, longitudinal study and multivariate analysis study are warranted to assess changes in auditory pathway maturation over time, and to determine whether the prolongation of wave latencies is temporary or permanent; and also the specific risk factor that may contribute the differences of latency wave in ABR result. Future analyses should also include amplitude parameters, wave morphology, and frequency-specific responses to enhance the understanding of the neurophysiological mechanisms of hearing in children with GDD. Comparative studies between GDD and typically developing children will provide additional diagnostic value in understanding the dynamics of central nervous system maturation, and contribute to the development of audiological screening guidelines for at-risk pediatric populations in Indonesia.

This study concluded that there was a significant difference between the absolute latency of wave V in the left ear at male group among children with global developmental

delay (GDD) compared to female group. Other perinatal risk factors, including gestational age, birth weight, history of NICU admission, asphyxia, and hyperbilirubinemia, did not show a significant difference in Auditory Brainstem Response (ABR) wave latencies in the GDD population.

ACKNOWLEDGEMENT

We would like to express our sincere gratitude to the Department of Otorhinolaryngology–Head and Neck Surgery, Division of Pediatric Otolaryngology, Dr. Cipto Mangunkusumo National General Hospital, for their valuable collaboration and support in this study. Their dedication and expertise in managing hearing-related problems among infants and children, greatly contributed to the completion of this research.

.

REFERENCE

1. Soebadi A, Anidar, Kurniawan A, Widodo DP, Nur FT, Pusponegoro HD, et al. Proceedings of update in child neurology: everything you should know about motor and movement problems in children. Jakarta: IDAI Jakarta; 2017.
2. Shevell M, Ashwal S, Donley D, Flint J, Gingold M, Hirtz D, et al. Practice parameter: evaluation of the child with global developmental delay: report of the Quality Standards Subcommittee of the American Academy of Neurology and the Practice Committee of the Child Neurology Society. Neurology. 2003;60:367-80.
3. Suwarba IGN, Widodo DP, Handryastuti RAS. Profil klinis dan etiologi pasien keterlambatan perkembangan global di Rumah Sakit Cipto Mangunkusumo Jakarta. Sari Pediatri. 2008;10(4):255-61.
4. Vitrikas K, Savard D, Bucaj M. Developmental delay: when and how to screen. Am Fam Physician. 2017;96(1):36-43.
5. Ali SS, Balaji PA, Dhaded SM, Goudar SS. Assessment of growth and global developmental delay: a study among young children in a rural community of India. Int Multidiscip Res J. 2011;1:31-4.
6. Almahmoud OH, Abushaikha L. Developmental delay and its demographic and social predictors among preschool-age children in Palestine. J Pediatr Nurs. 2024;74:101-9.
7. Rusli V, Suryawan A, Irmawati M, Irwanto I, Notobroto HB. Risk factors of speech and language disorders in children. Paediatr Indones. 2024;64(5):430-8.
8. Echeverria-Palacio CM, Uscategui-Daccarett A, Talero-Gutierrez C. Auditory, visual and proprioceptive integration as a substrate of language development. Rev Fac Med. 2018;66(3):469-75.
9. Suwento R, Zizlavsky S, Hendarmin H. Gangguan pendengaran pada bayi dan anak. In: Soepardi E, Iskandar N, Bashiruddin J, Restuti R, editors. Buku ajar ilmu kesehatan telinga hidung tenggorok kepala dan leher. 7th ed. Jakarta: Badan Penerbit FKUI; 2012. p. 30-5.
10. Fuess VLR, Bento RF, Silveira JAM. Delay in maturation of the auditory pathway and its relationship to language acquisition disorders. ENT Ear Nose Throat J. 2002;81(10):706-12.
11. Sharma M, Bist SS, Kumar S. Age-related maturation of wave V latency of auditory brainstem response in children. J Audiol Otol. 2016;20(2):97-101.
12. Lotfi Y, Abdollahi FZ. Age and gender effects of auditory brain stem response. Iran Rehabil J. 2012;10(16):30-6.
13. Stipdonk LW, Weisglas-Kuperus N, Franken MC, Nasserinejad K, Dudink J, Goedegebure A. Auditory brainstem maturation in normal-hearing infants born preterm: a meta-analysis. Dev Med Child Neurol. 2016;58(10):1009-15.
14. Angrisani RG, Diniz EMA, Guinsburg R, Ferraro AA, Azevedo MF, Matas CG. Longitudinal electrophysiological study of auditory pathway in small for gestational age infants. CoDAS. 2014;26(4):294-301.
15. Jiang ZD. Maturation of peripheral and brainstem auditory function in the first year following perinatal asphyxia: a longitudinal study. J Speech Lang Hear Res. 1998;41(1):83-93.
16. Salehi N, Bagheri F, Ramezani Farkhani H. Effects of hyperbilirubinemia on auditory brainstem response of neonates treated

with phototherapy. Iran J Otorhinolaryngol. 2016;28(84):23-9.

17. Costanzo L. Audition. In: Physiology. 6th ed. Philadelphia: Elsevier; 2018. p. 91-5.
18. Aggarwal A, Mittal H, Patil R, Debnath S, Rai A. Clinical profile of children with developmental delay and microcephaly. J Neurosci Rural Pract. 2013;4(3):288-91.
19. Angrisani RM, Bautzer AP, Matas CG, Azevedo MF. Auditory brainstem response in neonates: influence of gender and weight/gestational age ratio. Rev Paul Pediatr. 2013;31(4):494-500.
20. Burkard RF, Don M, Eggermont JJ. Auditory evoked potentials: basic principles and clinical application. Philadelphia: Lippincott Williams & Wilkins; 2007.
21. Hood LJ. Clinical applications of the auditory brainstem response. San Diego: Singular Publishing Group; 1998.
22. Jiang ZD, Brosi DM, Wu YY, Wilkinson AR. Relative maturation of peripheral and central regions of the human brainstem from preterm to term and the influence of preterm birth. Pediatr Res. 2009;65(6):657-62.